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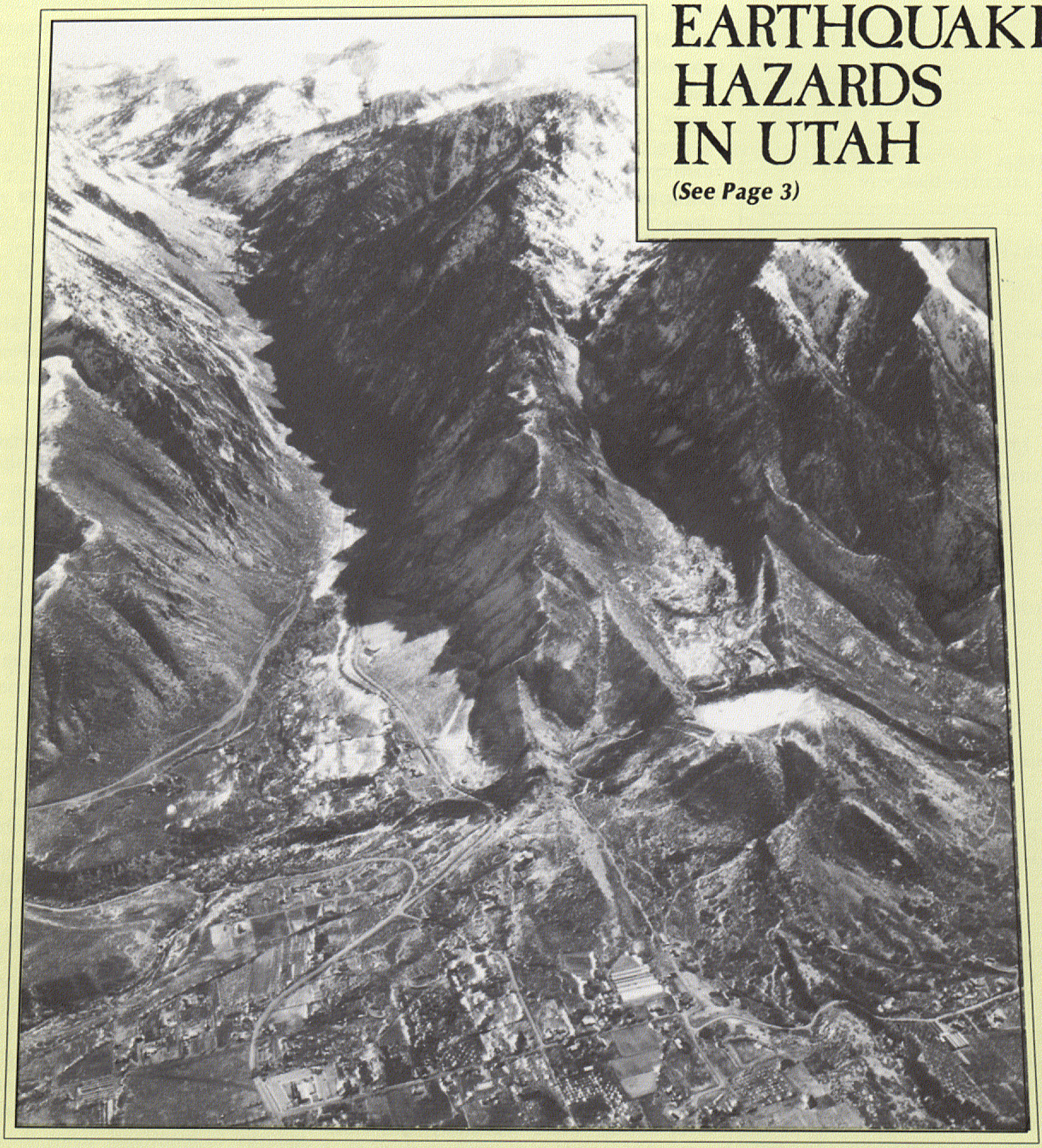
EARTHQUAKE HAZARDS IN UTAH

(See Page 3)



Wasatch fault at the mouth of Little Cottonwood Canyon, Southeast of Salt Lake City. Latest movement on the fault here pre-dates historic record but the fault has displaced young Quaternary alluvium and glacial moraine probably during the last 1000 years. Photograph courtesy of Lloyd Cluff and George Brogan.

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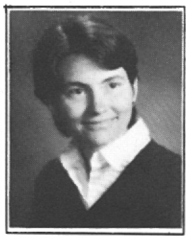

FROM THE DIRECTOR'S DESK

Earthquake Hazard Mitigation

DON MABEY'S article in this issue of *Survey Notes* sets forth the historic and scientific context for understanding the earthquake hazard along the Wasatch Front. Decisionmakers should consider certain of his conclusions when taking actions to reduce the risk from earthquake hazards: (1) although Utah experiences far fewer earthquakes than California, ample geologic evidence indicates that a major earthquake event ("the whopper") could occur at any time; (2) even if the whopper doesn't occur for another century, several historic earthquakes provide ample evidence that less major events that we know occur more frequently will cause extensive damage which will make the flooding and landslide events of 1983 and 1984 look minor in comparison, (3) approximately 90% of Utah's population is in the zone of high risk, and (4) the next major earthquake in Utah will probably occur without warning.

ACTION DILEMMAS

Because earthquakes are infrequent events, decisionmakers have considerable latitude in taking action. They probably will not be accountable for the actions they don't take. Attitudes range from "it won't occur in my lifetime so why worry about it" to suggestions that all possible actions regardless of cost should be taken to reduce the risks because the whopper could occur today.

In addition to the historic and scientific context, decision makers are faced with political, economical, philosophical and ethical components of earthquake hazard reduction which are very complex. Among these are:

Acceptable risk — most of us accept risk as a part of daily living, e.g., crossing the street, driving to work, etc. etc. Policy makers often have to assess the acceptability of certain risks to society, e.g., a high level nuclear waste repository, the Vitro tailings site, storage of chemical warfare weapons, etc. etc. Destructive earthquakes do not happen often in Utah, but their consequences could be devastating. Is it reasonable to accept such devastation as an "acceptable risk"?

Risk assessment — a complicating factor for decisionmakers is that earthquake risk is not well understood. Virtually all earth scientists look upon major earthquakes along the Wasatch fault as a certainty, but cannot predict where they will occur or exactly the damage they will cause.

Responsibility to communicate — organizations such as the UGMS, the USGS, and the U of U Seismograph Stations produce the most up-to-date information about the risk and communicate their findings to policy makers. What responsibility do these governmental entities and individuals within them have to communicate this information to the public?

Paternalism — government has the responsibility to protect the lives, health, and property of its citizenry. When is it appropriate to interfere with individuals' decisions in order to protect them?

Weighing the values — sometimes the values of society are conflicting. For instance, the social value placed upon historic preservation can be counter to the seismic risk created by old, poorly reinforced structures.

IDEAS FOR 1985

At the UGMS, we've thought a lot about these dilemmas. We produce some of the information about earthquake risk along the Wasatch Front, use information produced by others, disseminate information to users, and advise policy makers about earthquake hazard reduction. The good news is that major advances in our understanding and response to earthquake hazards are taking place right now. The large 3-year USGS effort targeting the geologic hazards of the Wasatch Front, the enthusiasm of the architects and construction industry to meet and define their alternatives for hazard reduction, and the increas-

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EARTHQUAKE HAZARDS I·N U·T·A·H

By DON R. MABEY

OUR UNDERSTANDING OF THE earthquake hazard in Utah is based on earthquakes experienced in Utah, earthquakes that have occurred elsewhere in the western United States, our knowledge of the geology of Utah, and research on earthquake mechanisms and effects. This understanding, which has developed over the 137 years since permanent settlements were established in Utah, has led most, if not all, scientists who have studied the problem to conclude that the area of Utah where 90 percent of the State's population reside is in an active seismic zone with an earthquake hazard that deserves the attention of officials and the general public. Because Utah has never experienced a highly destructive earthquake in a heavily populated area, the earth scientists must convince the community of the hazard and work with decisionmakers to recommend appropriate actions to provide the desired degree of protection for life and property. The Utah Geological and Mineral Survey (UGMS) and the U.S. Geological Survey (USGS) are working in a cooperative effort to develop an improved understanding of the earthquake hazard in Utah and provide to government, private groups, and individuals information on the hazard that can be used to develop programs to reduce the losses when an earthquake occurs. This effort is part of a long-term commitment by the USGS to support earthquake studies in Utah. The USGS research program through its extramural contractors and internal program has made important advances in understanding Utah earthquakes. As a cooperative partner the State of Utah has been a long-time supporter of the University of Utah Seismograph Stations in these efforts.

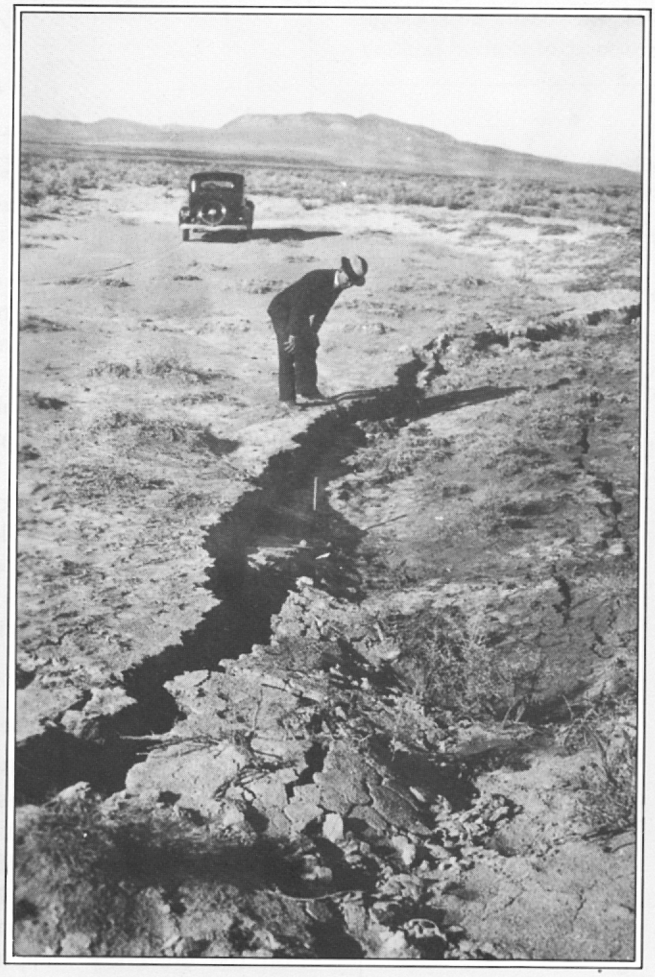

FIGURE 1. *Fault scarp formed in Hansel Valley north of Great Salt Lake in the 1934 earthquake. Photograph courtesy of Wilbur Smith from the collection of the University of Utah Seismograph Stations.*

HISTORIC EARTHQUAKES

Early Earthquakes

The first earthquake reported in Utah was felt in Nephi and Provo on December 1, 1853, six years after the first Mormon settlements were established. The *Deseret Weekly* for December 15, 1853, reported,

> *Fort Nephi, Dec. 1, 1853; There was a very sensible shock of an earthquake experienced by the inhabitants of this place at 11h. 15m. A.M. this day; so much so that the inmates of the houses left them in fear as the roofs moved visibly in some places. It seemed to approach this place from the northeast, lasted about one minute and passed off in a southern direction with a rumbling noise heard at intervals for half an hour.*

Over the next 18 years, two earthquakes were reported: one in Parowan in 1859 and the other in Ephraim in 1868. In 1872 and 1873, four earthquakes were reported in Utah and from 1872 through 1885, 40 earthquakes had been reported. Activity was lower from 1886 through 1893, although an increasing population and number of newspapers in Utah would be expected to result in an increase in the number of earthquakes felt and reported. The increased earthquake activity reported between 1872 and 1885 is very likely a real increase in number of earthquakes occurring. A large earthquake probably located in the Bear Lake Valley was felt throughout northern Utah on November 10, 1884. Damage was reported in Bear Lake and Cache Valleys and aftershocks were felt through November 13. The earthquake has been assigned a magnitude of 6.3 on the Richter scale. On November 13, 1901, a large earthquake occurred in the Richfield area causing considerable damage and this was followed a year later on November 17, 1902, by a large earthquake that caused considerable damage in the St. George area. These two events have been assigned magnitudes of 7.0 and 6.3 respectively.

Several earthquakes outside of Utah have been important in understanding the earthquake hazard in Utah and have influenced the development of earthquake research in Utah. An earthquake occurred in Owens Valley, California in 1872 and destroyed the town of Lone Pine. Of the 250 to 300 inhabitants of the town, 27 were killed and about 60 injured, and 52 of the 59 houses in the town were destroyed. This earthquake, on the west edge of the Basin and Range Province, revealed the destructive power of normal faulting

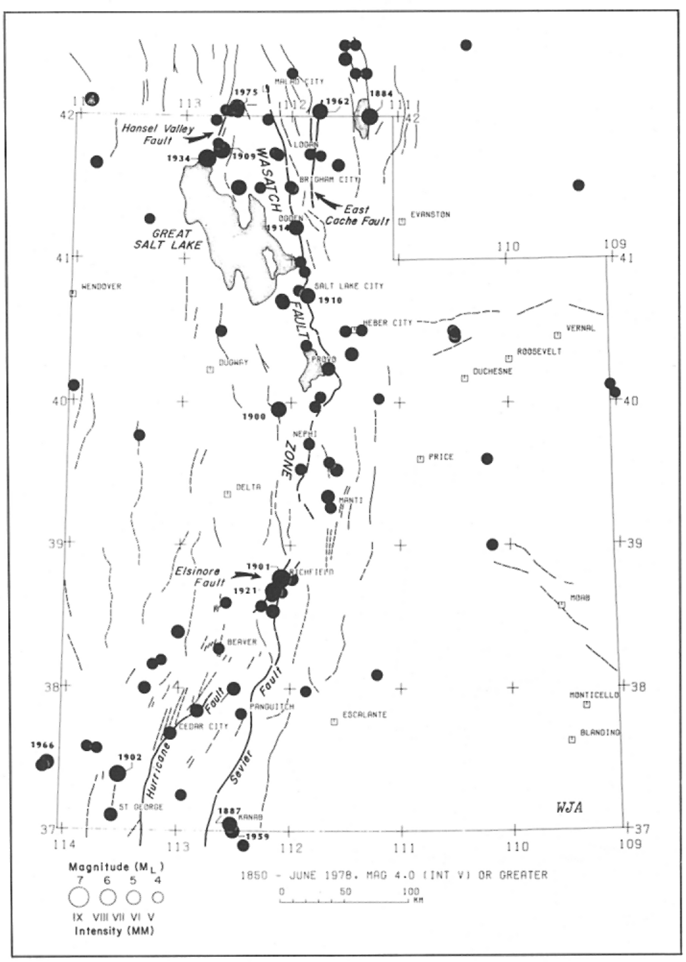

FIGURE 2. *Historic earthquakes in Utah magnitude 4 or greater and fault map. (from Arabasz and Smith, 1979).*

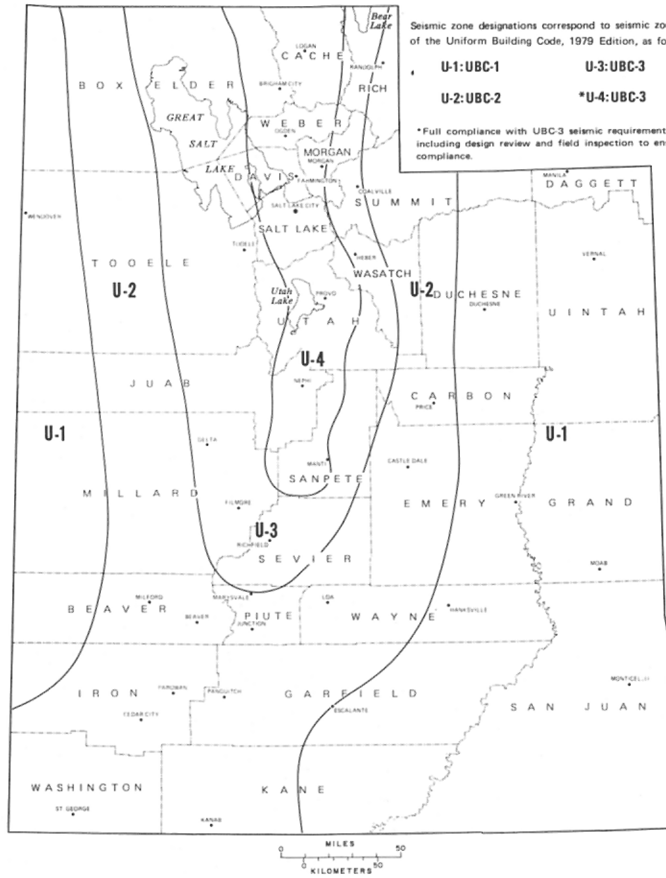

FIGURE 3. *Utah Seismic zones recommended by the Utah Seismic Safety Advisory Council, January, 1980.*

earthquakes characteristic of the Wasatch Front. G.K. Gilbert, who had been working in Utah, visited Owens Valley and recognized the implications this earthquake had to Salt Lake City. He wrote a letter to the *Salt Lake Daily Tribune* which was published on September 16, 1883. The letter explained the geologic evidence that major earthquakes had occurred along the west side of the Wasatch Mountains in pre-historic time, and that they would continue to occur. Gilbert concluded that little would be done to protect the citizens of Salt Lake City before the first disasterous earthquake. (The complete text of Gilbert's letter and a note on the letter by James F. Peterson were printed in the Autumn 1983 issue of *Survey Notes.*)

Instrumentation and Research

The great San Francisco earthquake of 1906 stimulated interest in earthquakes and instruments to record earthquakes. James E. Talmage, who was President of the University of Utah from 1894 to 1897 and Deseret Professor of Geology from 1894 to 1907, had been working for several years to obtain support for the installation of a seismograph on the university campus. He finally succeeded in 1907 when a seismograph was installed in the basement of the museum (now the James E. Talmage Building). This instrument probably was moved to the Seismograph Laboratory

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LOOKING BACKWARD

By Wm. LEE STOKES

Early Workers in the Wasatch

James E. Talmage, president of the University of Utah, 1894-97. He served simultaneously as head of the Department of Geology. He made significant contributions to science but is better known as a churchman and educator. Photo courtesy of Marriott Library, University of Utah.

THE FIRST geologic studies in northern Utah that resulted in geologic maps and cross-sections were conducted by the 40th Parallel Survey under the wonder boy of the time, Clarence King. The main field camp for a while was at Salt Lake City and the Wasatch Range received special attention. King's interpretations of the spectacular mixture of sedimentary, metamorphic, and igneous rocks in the central Wasatch was influenced by what he had seen in the east and in the Colorado Rockies. He believed that the granite bodies of the central Wasatch were Archaean and wrote, "The chain of outcrops clearly represents an old Archaean range of bold configuration which has been (buried) beneath an enormous accumulation of Paleozoic and Mesozoic sediments. It was this buried Archaean range which controlled the position and direction of the modern Wasatch Range." Although King did consider the possibility of an intrusive origin he literally talked himself out of the idea.

Local geologist, James E. Talmage, had different views. He was the first Chairman of the Department of Geology at the University of Utah. His observations were elementary but decisive — he found fragments of Paleozoic rocks as xenoliths in the granite. Being a generous and trusting soul, he gave this information to S. F. Emmons, King's right hand man on Wasatch studies. Subsequently Talmage wrote to his son, Sterling, also a geologist, "One of the serious mistakes I made during my professional career was the failure to publish properly. I have lost the credit of some important work through priority of publications by others, for example the identification of the Cottonwood granite as a laccolith and not as a mere Archaean mass." It was Emmons who corrected the mistakes of King, his superior, but he gave no credit at all to the man who discovered the critical facts. He did acknowledge the criticism of Archibald Geike who had expressed in print a disbelief in the probability of the 30,000-foot high Archaean cliff that King's hypothesis required. But geologists of the King Survey went forward across the Great Basin and mapped many crystalline outcrops as protrusions on a great unbroken Archaean basement.

Looking Backward
Sixth and final article in a series

It was not until a few years ago that the Cottonwood stock was dated as 30 to 40 m.y. old and the intruded sediment as over one billion years old, to create a difference in age more extreme than King could have dreamed of.

Closing Remarks

But I must close, and with a confession — I have crossed a few faults myself, both actually and figuratively, without recognizing them. Worse than this, I have caused some of my students to do the same. For this I am sorry and repent.

But I cannot agree with Shakespeare, who in Julius Caesar, has Anthony in the funeral oration declare that, "the ill that men do lives after them, the good is oft' interred with their bones." This may be true of generals, politicians, and even statesmen — today their mistakes are shooting it out everywhere. No, it is the good work of geologists that lives on to build science — the bad is interred in their literature.

So I say, do not cross faults if you can avoid it. Learn to recognize them. They are tricky at hiding under the sagebrush or alluvium and in camouflaging themselves as innocent bedding planes or as ordinary unconformities. But if you miss a few, do not worry; join the club. ■

EARTHQUAKE HAZARDS IN UTAH
Continued from Page 4

1935. Unfortunately these early records were lost and have not produced much information on local earthquakes (Arabasz, 1978).

Work by Gilbert, W.M. Davis, and others, provided geologic evidence of the earthquake hazard represented by the active faults in western Utah, and earthquakes provided proof. Major earthquakes in western and central Nevada in 1915 and 1932 added confirmation of earthquake hazards related to Basin and Range structures. In March 1934, a large earthquake occurred in Hansel Valley in northwestern Utah directly causing one death. A scarp five miles long with vertical displacement up to 20 inches developed (fig. 1). The Hansel Valley earthquake with magnitude of 6.6 produced more deformation than any other earthquake in Utah's historic record.

IN THE 1930s significant advances were made in earthquake instrumentation in Utah. The Seismograph Laboratory Building on the University of Utah campus was completed in 1935 and in cooperation with the U.S. Coast and Geodetic Survey (USCGS) the instruments were upgraded in 1939. Utah's first strong motion accelerograph was installed in the Oldham Seismograph Station at Utah State Agricultural College in Logan, and a conventional seismograph was added in 1940. From 1939 until 1962 seismograph records from Utah were routinely forwarded to the USCGS. As more and better data on Utah earthquakes became available, more earthquake research was undertaken and overviews reported. This included a summary of the earthquake history of Utah, 1850-1949 by Williams and Tapper (1953).

Improved instrumentation and more funding for research since the 1940's has greatly increased our knowledge of the earthquake hazards in Utah. The destructive power of earthquakes in the region was again demonstrated by major earthquakes at Fairview Peak, Nevada in 1954 and at Hebgen Lake, Montana in 1959. The latter killed 28 people, including 12 Utah residents. The Hebgen Lake earthquake increased the earthquake awareness in Utah and in 1961, K.L. Cook, the Chairman of the Department of Geophysics at the University of Utah, established two new seismograph stations. This was the beginning of the network that in 1966 became the University of Utah Seismograph Statons. In August 1962, a few months after the network went into operation, an earthquake in northern Cache Valley caused about $1,000,000 in damage. Alaska's Good Friday earthquake in 1964 and the San Fernando Valley, California earthquake in 1971 attracted national attention to the hazards of earthquakes in urban areas and Federal funding for earthquake research increased. Federal programs have provided important support for research related to Utah's earthquake hazard and for expanding and improving the network of seismograph stations operated by the University of Utah. In 1975, the Pocatello Valley earthquake near the Utah-Idaho border caused considerable damage, mostly in Idaho. In recent years earthquake research at the University of Utah under the direction of R.B. Smith and W.J. Arabasz has made major contributions to understanding Utah earthquake hazards. (For a collection of papers summarizing this work through 1978 see "Earthquake studies in Utah 1850 to 1978," edited by W.J. Arabasz, R.B. Smith and W.D. Richins.

Borah Peak Earthquake

The Borah Peak earthquake, which occurred in central Idaho on October 28, 1983, is proving to be of great importance to understanding Utah's earthquake hazards. The geologic setting of this earthquake is similar in important ways to Utah's Wasatch Front. The similarities include:

1. A large mountain range (the Lost River Range) on the east side of an intermountain valley rises abruptly about 6,000 feet above the valley.

2. A fault scarp with strong evidence of recent movement lies along the base of the range and the facetted range front indicates that faulting is the primary cause of the relief between the valley and the range.

3. The range front is not a continuous linear feature but is segmented into several units.

4. The range is made up primarily of pre-Tertiary rocks that have been involved in major Mesozoic overthrusting.

5. There is no evidence of Neogene volcanic activity.

Prior to the earthquake, the fault along the base of the Lost River Range had been identified as an active fault capable of producing a major earthquake, but no concentration of seismicity had been recorded. No precursors of the earthquake have been identified but it occurred in a sparsely populated area and not within a regional network of seismograph stations.

The Borah Peak earthquake, which has been assigned a magnitude of 7.3, was the largest earthquake in the conterminous United States since the Hebgen Lake earthquake in 1959. Two children were killed in Challis when the front of a building collapsed onto a sidewalk. The earthquake was felt over a wide area including Salt Lake City about 250 miles to the south. Damage was widespread and is estimated at $12.5 million. Buildings in Mackay and Challis experienced severe damage from ground shaking, and rockfall damage occurred in Challis. However, the damage to these communities was not as great as many would have predicted from an event of this magnitude. A zone of surface rupture 22 miles long formed along the base of the Lost River Range. Over most of the length the zone was coincident with Holocene and upper Pleistocene scarps of the Lost River fault. The scarps formed during the earthquake had a maximum displacement of 8.8 feet. No significant culture features existed in the rupture zone except for roads which were offset and blocked. A landslide and debris flow moved where a group of springs were disturbed in the rupture zone. Numerous rock falls occurred, but no other major landslides or debris flows at the time of the earthquake have been reported. The epicenter was about 8 miles southwest of the south end of the rupture zone. Numerous aftershocks have occurred mostly in a zone extending north-northwest from the epicenter and west of the surface rupture. (R.B. Smith, written communication, 1984). The location of the epicenter and the aftershocks suggest that the Lost River fault zone dips about 45 degrees to the west. The main event was at a depth of about 10 miles and most of the aftershocks have been between 3 and 9 miles below the surface.

One of the most dramatic effects of the Borah Peak earthquake was on the hydrology. The flow of water entering the Clayton Silver Mine about 32 miles northwest of the epicenter approximately doubled forcing the mine to close. Discharge in many springs and streams in the region increased and Old Faithful Geyser in Yellowstone National Park 150 miles to the east was affected. Severe liquefaction resulting in large sand boils developed in Thousand Springs Valley near the southern end of the rupture zone. A large volume of water erupted from fractures in a limestone butte in the valley and piping developed in an area of the butte where a veneer of alluvium covered the bedrock (fig. 5). The largest debris flow related to the earthquake occurred after the earthquake and was a result of the hydrologic effects.

The Borah Peak earthquake appears to be the best example of an historic earthquake similar to what might be expected along the Wasatch Front. However, caution should be exercised in transferring the knowledge gained along the Lost River fault to the Wasatch Front. The valleys along the Wasatch Front are larger than the valleys west of the Lost River fault and filled to greater depths with Cenozoic rocks and this will intensify the effects of ground shaking. Great Salt Lake and Utah Lake pose a problem that does not exist in the Lost River region. Although near surface dips of the Lost River and Wasatch faults appear similar, the evidence of a listric character (dip decreasing at depth) is stronger for the Wasatch fault. And perhaps most important, the historic seismicity of the two areas is very different with the Lost River fault being less active.

WASATCH FRONT EARTHQUAKE HAZARD

Although a destructive earthquake could occur anywhere in Utah, both the geologic evidence and the historic seismicity indicate that such events are much more likely to occur in a zone trending generally north across western Utah along the eastern edge of the Basin and Range province, a part of the Intermountain seismic belt that extends north into Montana. The front of the Wasatch Range in northern Utah and the west edge of the Colorado Plateau indicate large and continuing displacement that must have been accompanied by major earthquakes. Young fault scarps, some as young as a few hundred years, occur throughout the zone. Trenching has revealed repeated displacement of young sediments (Schwartz and Coppersmith, 1984). Historic earthquakes have been concentrated in this zone (fig. 2). The Colorado Plateau to the southeast is now, and has been for a long period of geologic time, a relatively stable region. Evidence of Quaternary faulting on the Colorado Plateau is very sparse and most of the earthquakes recorded from the region appear related to mining activity. West of the most active seismic zone major earthquakes do occur, but less frequently than in the active zone.

Much more attention has been given to the earthquake hazard along the Wasatch Front than to the southern part of the seismic zone. The much larger population at risk along the Wasatch Front justifies this emphasis; however, the earthquake hazard to the south of the Wasatch Front is severe and should not be ignored. On seismic zonation maps southwestern Utah has been placed in a lower zone than the Wasatch Front (fig. 3). This may not be justified. The earthquake hazard in southwestern Utah deserves greater attention and the validity of current seismic zonation maps for this region should be investigated. The following discussion is focused on the Wasatch Front; some of it is also applicable to the area to the south, but there are significant differences in the earthquake hazard of the two areas.

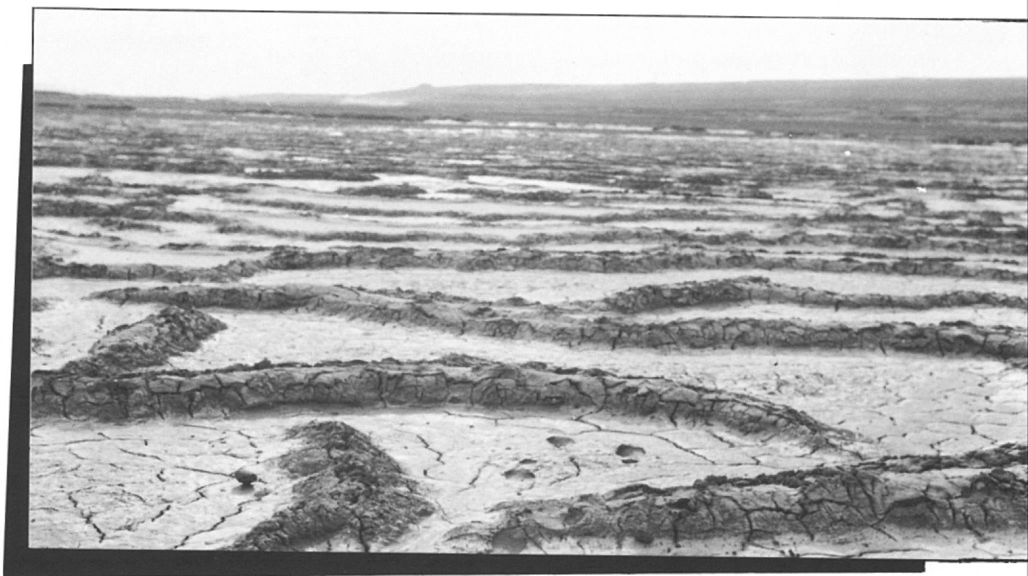

FIGURE 4. *Deformation of mud flats at the north end of Great Salt Lake caused by liquefaction associated with the 1934 Hansel Valley earthquake. Photograph courtesy Wilbur Smith from the collection of the University of Utah Seismograph Stations.*

To evaluate the earthquake hazard in a study area the following factors must be considered:

1. Where in the area and surrounding region are earthquakes likely to occur (source areas).

2. The recurrence interval of earthquakes in various magnitude ranges for each source area.

3. The intensity distribution of each source area.

4. The ground shaking response and possible surface rupture zones within the study area.

5. Secondary effects of ground shaking such as slope failures and dam failures.

Source Areas

The source areas are usually identified on the basis of evidence of recent faulting, historic or current seismic activity, or strain accumulation. In the Intermountain seismic belt it is likely that formation of each fault scarp was associated with one or more significant earthquakes. Thus every young fault scarp indicates one or more recent earthquakes. It is also likely that most (although perhaps not all) very large earthquakes in the region have produced some surface faulting. Thus the absence of young surface faulting suggests that the probability that a very large recent earthquake has occurred recently is low.

In many areas of the world the historic and current seismicity is a guide to the future seismicity. In these areas the number and magnitude distribution of earthquakes provides an indication of the probability of an earthquake of a given magnitude occurring within a given time interval. It is not known how valid this approach is in Utah; certainly it was not valid for the Challis-MacKay area of Idaho where the Borah Peak earthquake occurred in an area of relatively low historic seismicity.

Large strain accumulations accompany large earthquakes; therefore, measuring strain accumulations by monitoring the deformation of the earth's surface may indicate where earthquakes are likely to occur. Young fault scarps have been mapped along much of the Wasatch Front and along some of the ranges to the west. The historic seismicity along the Wasatch Front reveals seismic gaps where the number of earthquakes is much lower than elsewhere along the front. The significance of these gaps is unknown. They may indicate areas where strain is accumulating without any release by small earthquakes and thus a likely location for a large earthquake. On the other hand, they may indicate areas where strain is not accumulating. In evaluating the earthquake hazard along the Wasatch Front with the data presently available the assumption should be made that an earthquake can occur anywhere at any time along the front or along several ranges to the west.

Recurrence Interval

Estimates of recurrence intervals are based on determinations of the number of faulting events that have occurred over the past several thousand years. This can be done by dating fault scarps or displacement in recent sediments revealed in excavations. Estimates made from the existing information vary substantially but suggest a major faulting event occurs somewhere along the Wasatch fault on the average of about 450 years (Schwartz and Coppersmith, 1984). Recurrence intervals on faults west of the Wasatch fault are less well known. The area north of Great Salt Lake has been very active in historic time with three magnitude 6 or greater events in this century. Two zones of faulting younger than 10,000 years have been mapped in central and western Juab County. In the area east of the Wasatch Front, faults younger than 10,000 years old occur in Bear Lake Valley. Young faults also occur north and south of the Wasatch Front. The effects along the Wasatch Front due to earthquakes in adjacent regions would likely be less than for earthquakes of equal magnitude along the front but could cause major damage. Significant damage can also be produced by smaller earthquakes not associated with surface rupture. It is not possible to use fault trace mapping to determine recurrence intervals for these smaller events, but they are much more frequent than larger events. Some confidence can be placed in the average recurrence intervals determined from the analysis of recent faulting and additional research will refine estimates. However, the distribution in time and space varies widely from the average and the data do not provide a basis for predicting when and where the next earthquake will occur.

Intensity and Magnitude

The magnitude of an earthquake producing surface rupture is related to the surface displacement and the length of the rupture. Displacement can be measured at the surface or in excavations and the maximum length of rupture can be estimated from the length of the fault segments assuming that individual ruptures are confined within one segment. Based on this appproach, estimates of the maximum magnitude of a Wasatch Front earthquake range from 7.0 to 7.5. The minimum earthquake likely to be associated with surface rupture is about 6.6 but most mapped displacements suggest the larger events. For planning purposes a conservative assumption is that a magnitude 7.0 to 7.5 earthquake will effect some area of the Wasatch Front on the average every 300 years.

The area and intensity of the effect of an earthquake of a given magnitude varies widely depending upon the structure of the crust and upper mantle and the nature of the earthquake. Individual earthquakes in the western United States effect much smaller areas than do earthquakes of equal magnitude in the eastern United States. As noted earlier, the ground shaking intensities experienced by the two communities nearest the Borah Peak earthquake were lower than many would have predicted for this magnitude event. The distribution of intensities that will be associated with a major Wasatch Front earthquake remains a major uncertainty.

Ground Response

The nature of the ground motion that will occur at a site is dependent upon the geology in the immediate vicinity of site. For example, the ground motion at a site on consolidated rock will be much different from that on a thick sequence of unconsolidated sediments. A knowledge of the surface and subsurface geology can be used to make generalized predictions of ground motion to be expected from an earthquake of assumed size and location, but to provide data needed to design structures it is highly desirable to measure the ground motion in response to a moderate shaking event. For this purpose strong motion instruments are designed to record only when ground accelerations exceed a predetermined value. These instruments may be located within structures to record the motion of the structure or in direct contact with the earth's surface.

Secondary Effects

Ground shaking, surface rupture, and deformation accompanying a major earthquake can produce secondary effects that are very destructive. Some secondary effects of major concerns along the Wasatch Front are: (1) flooding caused by the failure of dams or other water containment structures, (2) landslides and mudflows (including landslides damming streams and subsequently failing catastrophically), (3) hydrologic effects such as liquefaction (fig. 4), piping (fig. 5), and increased spring discharge, (4) seiches (waves on an enclosed body of water such as a lake or tank), and (5) inundation caused by surface deformation (maps showing the inundation that might accompany a hypothetical M 7.5 Hebgen Lake size earthquake along the Wasatch Front have been developed by Smith and Richins, 1985).

CAUSE OF WASATCH FRONT EARTHQUAKES

To date most of our knowledge of the geology along the Wasatch Front has been gained by the mapping of surface geology or logging of shallow excavations. The understanding required to adequately evaluate the earthquake hazard requires information on the three-dimensional geology at least to the depths at which the earthquakes occur. Along the Wasatch Front some information is available from deep holes mostly drilled in the exploration for petroleum resources. The most important source of information, however, is from geophysical surveys, particular seismic reflection profiling, which can be used to map layering in the earth to great depths. R.B. Smith and R.L. Bruhn (1984) have analyzed seismic reflection profiles in western Utah and concluded that major segments of the Wasatch fault and several other faults in the region are moderate-angle faults dipping to the west with the dip decreasing at depth. At depths generally less than 10 miles these faults may merge with nearly horizontal surfaces. Because most earthquakes in the region originate above these depths, it is likely that these horizons coincide with a zone above which the earth's crust is deformed primarily by brittle failure that produces earthquakes and that below this zone deformation is primarily plastic and does not produce earthquakes. The dominant cause of deformation (and thus earthquakes) along the Wasatch Front is the general east-west extension of the earth's crust. As the Basin and Range Province moves westward relative to the more stable areas to the east and extends, stress accumulates in the crust until rupture occurs along the faults separating the valley blocks from the range blocks. In a major earthquake the initial rupture occurs near the base of the brittle zone. Because of the westward dip of the fault, the focus of the earthquake is several miles west of the fault and the epicenter (the point on the earth's surface directly above the focus) does not coincide with the surface trace of the fault. The effect of the faulting is to drop the valley block relative to the range block. Both blocks may be tilted toward the east. Important factors relating to the earthquake hazard are: (1) the epicenters (and most severe ground shaking) of major earthquakes associated with the Wasatch fault are likely to underlie the valley areas west of the fault; (2) subsidence and tilting accompanying a major earthquake may significantly alter the valley floor; and (3) the accumulation of strain across the fault can be monitored by measuring changes in the horizontal distance between points on the Wasatch Range and ranges to the west.

WASATCH FRONT EARTHQUAKE HAZARD REDUCTION PROGRAM

In 1983 the USGS added Urban and Regional Hazards as a new element in the National Earthquake Hazards Reduction Program and identified the Wasatch Front as the highest priority area for funding under this element. The USGS invited the UGMS to participate in developing the Wasatch Front program and in carrying out the program. The Wasatch Front program consists of five components: (1) information systems, (2) hazard evaluation and synthesis, (3) ground motion modeling, (4) loss estimation models, and (5) implementation. The UGMS has worked with the USGS in developing the overall program and has some role in each component.

Information Systems

The objectives of the Information System Component are:

1. To make data available to program participants.

2. To develop a system that assures that new data will be available in the form most useful to meet program objectives.

3. To devise a system to provide easy access by users to data in the forms most useful to them and,

4. To provide continuing information on objectives and progress of the program.

Because none of the USGS scientists-managers working in the program are headquartered in Utah, the UGMS has an important role in representing the program in Utah. Many inquiries concerning the program are received by the UGMS. The UGMS is working with the USGS Public Inquiries Office in Salt Lake City to provide information and data related to the program. The UGMS is preparing to publish a bibliography on earthquake publications in Utah. With partial funding support from the USGS, the UGMS has upgraded the UGMS computer system to facilitate handling of earthquake related data and information and is working with the USGS on the development of data and information systems.

Hazard Evaluation and Synthesis

Synthesis of existing data and research directed toward developing a better understanding of the potential for the occurrence of a damaging earthquake along the Wasatch Front is part of the Synthesis of Geological and Geophysical Data for Evaluation of Earthquake Hazards Component. Included in this component are research projects on earthquake mechanism, recurrence intervals, fault-trace mapping, fault segmentation, surface and subsurface geology that relates to the earthquake hazards, and monitoring of deformation and other phenomenon that may relate to the Wasatch Front earthquakes. Much of the research under this component of the program is a continuation or extension of existing work including research at the University of Utah Seismograph Stations supported by the USGS.

Current UGMS activities in this component are the use of geophysical and drill hole data in a study of the regional subsurface geology and regional hydrology in the valley areas along the Wasatch Front, the mapping of excavations that expose evidence of recent fault movement and the mapping of surface evidence of recent faulting in areas about to be disturbed by development.

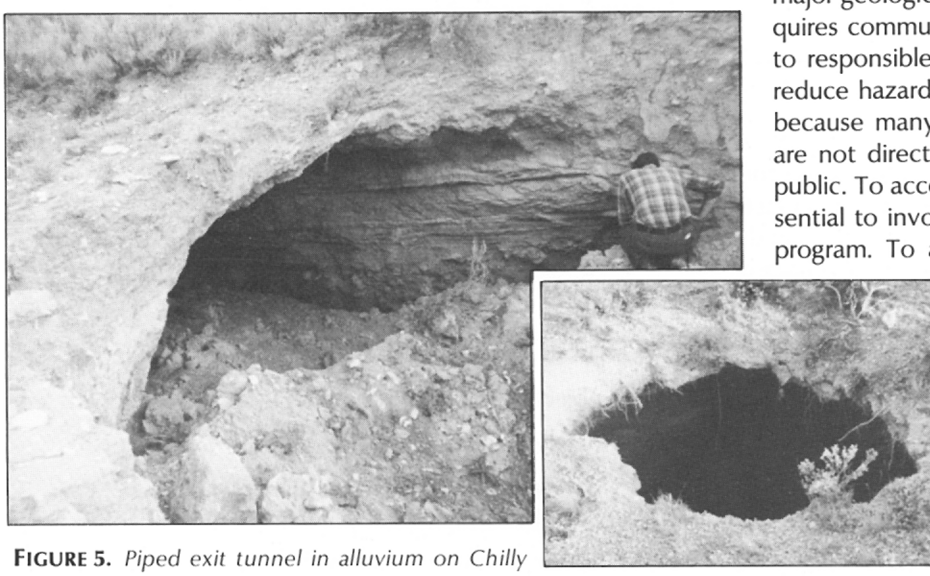

FIGURE 5. *Piped exit tunnel in alluvium on Chilly Buttes produced by ground water eruptions accompanying the Borah Peak earthquake. Inset - collapsed tunnel roof.*

Ground Motion Modeling

The Ground Motion Modeling component is concerned with prediction of the effects of local geology on ground shaking. The first priority is the preparation by the USGS of a synthesis report of all ground shaking data now available, and the second priority is to obtain additional data from geophysical surveys and strong-motion accelerographs. Several new strong-motion instruments have been installed in the Salt Lake City area in the last few months and other installations are planned for the near future. The UGMS role in this program is to work with the USGS in the design and installation of the strong-motion network and the design of the geophysical surveys. The final product of this component will be probabilistic ground shaking hazard maps that incorporate ground response.

Loss Estimation Models

The Loss Estimation Models component will use all available hazards data to develop economic loss and casualty estimates for several earthquakes of different magnitude and location. These loss estimates will provide a scientific basis for land-use planning the development of building codes and disaster mitigation, preparedness and relief programs. The first effort in this program is the update of the building inventory for Salt Lake City and the creation of an inventory of lifeline systems. The UGMS will assist the USGS in obtaining the data needed.

Implementation

The success of the Wasatch Front Earthquake Hazards Program in reducing the earthquake hazard will depend on the effectiveness of the Implementation component. The goal of this component is the effective use of scientific information to reduce loss of life and damage to property caused by major geologic and hydrologic hazards. To achieve this requires communication of translated scientific information to responsible officials and interested parties seeking to reduce hazards. This is a major challenge to the program because many of the products of the scientific research are not directly useable by responsible officials and the public. To accomplish the goals of this component it is essential to involve the user of the information early in the program. To accomplish this a series of workshops are being planned to work with user groups to define the kinds and format of information that would be most useful to them. The implementation component of the USGS-UGMS program is closely related to the preparedness and response programs of FEMA and the State Division of Comprehensive Emergency Management. Therefore, the four agencies are working together to develop this component. The UGMS is working with the Wasatch Front counties to use a grant from the USGS to place geologists in the county organizations. These geologists will compile hazards data within the counties and provide direct geologic input into the county governments. The UGMS will aide in the selection of the geologists and will provide coordination and technical review of their activities. The UGMS is also working with several local groups to develop proposals relating to implementation to be submitted to the USGS and FEMA for consideration for funding support.

CONCLUSION

The ultimate goal of much earthquake research is the prediction of earthquakes. Some major earthquakes that occur in intensely monitored areas are preceded by measureable geophysical and geochemical phenomena. These include changes in the number and distribution of minor earthquakes, deformation of the earth's surface, changes in earth resistivity and seismic velocity, waterlevel fluctuations and variations in soil gas. Aberrant animal behavior has also been documented, probably in response to the physical and chemical changes. Some of the precursors occur years before a major earthquake while others immediately precede the event. In California where many earthquakes have been intensively studied, general earthquake predictions are being attempted. In China actions taken in response to an earthquake prediction are credited with saving many lives. Earthquake prediction is a long-range goal of part of the Wasatch Front research; however, the first major earthquake along the Wasatch Front will probably occur without any warning to the public. The economic and social consequences of earthquake predictions are so serious that official predictions must be based on strong scientific evidence, which is not likely to exist before data from one or more major earthquakes along the Wasatch Front is available. Hopefully, sufficient monitoring will be available to identify some of the precursors of any major earthquake that occurs.

Water injection or withdrawal to control subsurface pressure has been demonstrated to provide some control over earthquakes in special geologic settings. The possibility that this or other approaches might be used to provide controlled release of strain through numerous small non-destructive earthquakes and thus avoid large destructive earthquakes has been investigated. No practical method of controlling earthquakes appears likely within the foreseeable future and research on earthquake control is not a part of the Wasatch Front program.

Earthquake research over the last two decades has greatly increased our understanding of the earthquake hazard along the Wasatch Front, and research now in progress will improve this understanding. How this knowledge of the earthquake hazards will be used by government, private organizations, and individuals to reduce the threat of life and property remains to be determined. An important role of the UGMS and other earth scientists involved in the earthquake program is to provide decisionmakers and individuals information on earthquake hazards that they can understand and use to provide the desired degree of protection from earthquakes. If we are successful and if the decisionmakers and individuals act on the information we can avoid the situation that G.K. Gilbert predicted 101 years ago when he wrote,

> *Our occupation of the country has been too brief for us to learn how fast the Wasatch grows: and, indeed, it is only by such disasters that we can learn. By the time experience has taught us this, Salt Lake City will have been shaken down and its surviving citizens will have sorrowfully rebuilt it of wood: to use a homely figure, the horse will have escaped, and the barndoor, all too late, will have been closed behind him.*

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HAZARDS GEOLOGISTS FOR WASATCH FRONT COUNTIES

The Utah Geological and Mineral Survey (UGMS) and the U.S. Geological Survey (USGS) have approved a cooperative program to provide funding and technical assistance to counties so they can employ three hazards geologists to work in the five most populous Wasatch Front counties. A geologist will be employed by Weber County to work in Weber and Davis Counties. A geologist employed by Utah County will work in Utah and eastern Juab Counties and the third geologist will be employed by Salt Lake County. Each geologist will be part of the county planning department and their services will be available to other county departments and to the cities within the counties. It is expected that the geologists will be on board before the 1985 landslide and flood season. Funding of all salaries and benefits will be paid by a grant from the USGS to the UGMS. The UGMS will provide technical assistance, technical supervision, and specialized equipment.

The three-year effort is part of the Wasatch Front Earthquake Hazards Reduction Program and is designed to aid the counties and cities in obtaining information on geologic hazards within their jurisdictions and to provide improved access to geologic expertise on problems involving geologic hazards.

The County Hazard Geologists will compile information on geologic hazards and pull together in a single location all the hazard-related investigations already completed for each county. An end product of the three-year program will be maps and reports describing the geologic hazards in the counties. These final products will be published by the UGMS. ■

THE ALTA CONFERENCE

*The Alta Conference convened in July 1984, to discuss priorities for geologic investigations in Utah. In the Autumn issue of **Survey Notes**, the first three reprints were published (Structure and Composition of the Crust, Dating Geologic Materials in Utah, and Geologic Hazards). The following articles are the last three of six which summarize the findings of these working groups.*

SEDIMENTARY ROCKS (BASINS)

By THOMAS D. FOUCH [1]

THE OBJECTIVES defined by the Sedimentary Rock Workshop were:

1) To provide a coordinated and multidisciplinary approach to research studies of sedimentary rocks and their constituents and to the evolution of sedimentary basins, ancient and modern. 2) To explore the interaction among mineral or sediment grains, biologic constituents, and fluid or gaseous constituents from the time of deposition or formation through various stages of basin formation, burial, uplift, and thermochemical alteration. 3) To develop and utilize new information from study of surface exposures in combination with interpretation of subsurface borehole geophysical, electrical, and lithologic logs, cored rock, and gravity, magnetic, and seismic reflection and refraction interpretations to form an integrated geologic framework. 4) To develop and distribute new maps, charts, analyses, and data, and to offer state-of-the-art interpretations of this information, and 5) to provide current resource and hazard evaluations in a timely manner.

Strategy

Initial studies are generally regional in scale and designed to provide the geologic framework and context for subsequent detailed mapping, topical, and resource investigations. Detailed and topical studies are most effective when the regional sedimentary-basin framework has been established.

Base Program

A basin-studies program involves multidisciplinary studies and requires a strong

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[1] Chief, Energy Minerals Branch, U.S. Geological Survey.

HARD ROCK RESOURCES

By HAL T. MORRIS [2]

THE HARD Rock Resources workshop of the UGMS largely focussed on the following general observations and broad and specific guidelines:

1. Studies of the major mining districts and mineral resources, which have been underway in Utah for about 100 years, are no longer within the capability of individual generalist-geologists.

2. During the past few decades, the science of geology has become so highly diversified, multifaceted, and interdependent on the allied sciences of physics and chemistry that only through the collaborative efforts of many scientist-specialists can comprehensive studies and investigations be successfully undertaken.

3. Such forthcoming studies must be made at all levels of scientific complexity and all scales from isotopic and microscopic considerations based on experiments and measurements in sophisticated laboratories to the broadest scale field reconnaissance studies covering many thousands of square kilometers.

4. A great need exists for more interaction between scientists of different disciplines and a continuing effort must be made to promote collaborative studies and to sponsor greater attempts at the integration of data. Perhaps this role can best be filled by the USGS and UGMS.

5a. Because of the requirement for high-cost and sophisticated instrumentation, the University of Utah and the USGS probably should be the centers of this type of research for the foreseeable future. Such work, among other goals, should be directed toward the construction of genetic models of ore deposits, and an understand-

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[2] Geologist, U.S. Geological Survey.

SURFACE MAPPING

By LEHI F. HINTZE [3]

THE MOST obvious impression that came out of the two-day workshop was the repeatedly-expressed support for the UGMS 7.5-minute quadrangle mapping program. The present UGMS mapping priority system favors quadrangles with geologic, resource, and/or hazards importance, so it is perhaps not surprising that the most supportive discussions came from mining representatives and hazards workers. Hazards workers repeatedly expressed their concern that UGMS-funded mapping incorporate as detailed a breakdown of Quaternary units as feasible in view of their importance in hazard evaluation. Mining geologists stated that well-mapped 7.5-minute quadrangles form the springboard from which their other exploratory techniques are launched.

Participants also recommended completion of the 1:100,000 USGS topographic base map series for the State of Utah and their utilization for regional geophysical and geologic compilations that are best displayed at this smaller scale.

Participants recommended that UGMS support stratigraphic topical studies that would develop a more rational approach to map unit selection, particularly in selected stratigraphic intervals. It was also urged that radiometric dates be obtained and incorporated into explanations on maps produced by UGMS. Each of the topics touched on above is more fully discussed below.

UGMS 7.5-Minute Geologic Quadrangle Mapping Program

Two advisory boards have been established by UGMS Director Atwood: 1) Map

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[3] Professor of Geology, Brigham Young University

SEDIMENTARY ROCKS

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coordinator/leader for success. A base program should investigate the interaction among mineral and/or detrital, biologic, and liquid or gaseous constituents and will include:

1. Geologic surface and subsurface maps that establish and document the basin's fundamental rock units and that illustrate the stratigraphic, temporal, and tectonic rock relations.

2. Regional stratigraphy, sedimentology, and biostratigraphy, with particular emphasis on defining rock units in terms of lithofacies. Lithofacies should then be interpreted as depositional facies (genetic stratigraphy); and the occurrence of mineral and fuel resources should be related to this facies framework.

3. Petrography and petrology of rocks and chemical analyses of selected mineral, liquid, and gaseous components to determine the physiochemical changes that have altered the rock during diagenesis — particularly where such rock-fluid-gas interactions are critical to establishing 1) the sedimentary-rock habitat and resources of such mobile constituents as uranium, metallic elements, phosphorus, and oil and gas, and 2) the mechanisms of formation of emplacement of these constituents.

4. Thermal and hydrologic regime reconstructions that establish the interplay among patterns of subsurface pressures and fluid and gas flow, aqueous geochemistries, and their collective relation to natural resource and hazard matters.

5. Reconstructions of paleothermal regimes and geochemical facies that establish the nature and amount of organic matter formed and preserved in the sedimentary rocks and thermal conditions under which the organic matter 1) was/could be thermochemically transformed in the liquid or gaseous hydrocarbons, 2) could/did affect stages of mineral or fluid diagenesis, and 3) could/did serve as a complexing and transporting medium for metallic elements in basin fluids.

6. Provenance of temporally equivalent unaltered rocks to establish sources of sediments, and directions and nature of fluid and grain flow, documenting tectonic changes and influences, temporal relations, transport-energy regimes, biologic constituents and their interplay with fluids and grains.

Suggested Study Topics

1. Thrustbelt Architecture:

a. A study of the Great Blue Limestone depositional basin — the unit forms a particularly important host of metallic ores and is a critical unit for regional and local tectonic reconstructions. Great Blue investigations should include detailed but regional studies of lithofacies, and depositional facies within a chronostratigraphic framework. Regional and local patterns of mineral and elemental constituents are essential to establishing ore-deposit models and assessing the resources. Unit studies should include analyses of the role of organic matter, temperatures, and fluids in forming ore deposits.

b. Continued study of the Jurassic and Cretaceous rocks and structures and chronostratigraphy of central Utah with particular emphasis on collection and integration of geophysical data and interpretations with new results on the identity, lithologic nature, and heat history of rock units in the study area. Subsurface control points, increasingly available for calibration of the geophysical and other subsurface interpretations, place constraints on interpretations of the regional presence and lithofacies of rock units. Thrustbelt investigations should be posed to match and compare the nature of the synorogenic rock record of eastern Utah with that of central Utah and to explore the sediment-loading/geophysical mechanisms that may have effected renewed uplift of basement rocks in the foreland in the latest Campanian/early Maestrichtian.

2. Oquirrh Basin Evolution:

The Oquirrh Basin represents a thick sequence of sedimentary rocks that formed from sediments deposited in a quickly and continually subsiding basin. Rock thicknesses and depositional character suggest some quiet water (but not necessarily bathymetrically deep) deposition whose cumulative thickness suggests an unusually deep hole in the crust. Available geophysical and other data imprecisely define the structural limits and configuration of the basin. However, further study of the basin and geophysical modeling of its architecture would be limited by the lack of the deep basin boreholes needed to provide subsurface calibration points.

3. Paradox Basin Analysis:

The Utah Oil, Gas and Mining Division and the Utah Geological and Mineral Survey both have a continuing need for precise and well-defined base line geologic information on the regional hydrology, thermal history, porosity, permeability, and structure of basin rocks to enable them to respond to geologic-hazard and oil-and gas-regulatory matters. The USGS may be able to provide some expertise on Mesozoic and Paleozoic stratigraphy and sedimentology, and on oil and gas studies involving marine salts and subsequent structures. University of Utah expressed an interest in conducting hydrologic and geothermal studies. Industry activities are numerous and varied and industry cooperation can be expected. Abundant drill holes penetrate basin rocks—many to the "basement"—thus subsurface calibration for geophysical reconstructions seems possible. Such a program of basin studies in southeastern Utah would appear to respond to the continuing need of Utah agencies and the industry appetites for regional and local geologic information and it would provide excellent data bases for hydrologic and geothermal, depositional, tectonic, and organic geochemical process-oriented investigations.

4. Continued Uinta Basin Studies:

The Uinta Basin is an intermountain basin penetrated by many drill holes around the southern and eastern perimeter but only to the uppermost Cretaceous in its north central interior. The basin is host to an ongoing effort of hydrocarbon exploration with spotty success. Basin rocks, depositional facies, and hydrocarbons are perhaps comparable to compressional basins of the region extending from the northeast and central China with notable exceptions. UGMS investigators have led efforts to evaluate tar-sandstone and oil-shale deposits and to do oilfield studies and should continue to do so. The USGS plans to conduct a variety of studies in the basin as a part of its Uinta-Piceance Basin Evolution program and as a result of studies funded by the U S Department of Energy for evaluating "tight gas sands". USGS investigations will support and encourage university studies as much as possible. Dave Chapman (Univ of Utah) is conducting hydrologic, thermal, and subsurface-pressure studies and should be encouraged by the USGS and industry to do so.

5. Coal Studies:

Investigations of coal, methane in coal, and coal-bearing sequences have historically been a research focus of the UGMS and should continue to be so. Although similar talents and analytical capabilities exist in other private and governmental agencies, none has the resources, money, background, or state-directed interest to conduct the studies in a manner suitable for State needs.

6. Industrial and Nonmetallic Commodities:

The UGMS is encouraged to initiate a robust program to qualify, quantify, locate, and assess such industrial materials as industrial limestone and sand and gravel. These materials are principally of a local concern but they generally comprise an economic matter far more important than that of metallic ore production. Analytical equipment for routine analysis is not generally available to the UGMS or in state universities but can be locally obtained via industry. ■

HARD ROCK RESOURCES

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ing of the origin and physio-chemical environment of deposition of the mineralized bodies.

5b. Geochemical prospecting was judged to be a direct ore-finding technique used in the search for mineable ore bodies and thus was predominantly the responsibility of the mining industry — although it was recognized by some that exceptions to this guideline do exist.

6. Inasmuch as the mineral-resource activities of the USGS and UGMS are strongly oriented toward the industry user, the mining geologists were asked to list their expectations from the USGS, UGMS, and academia. The immediate and unqualified response was the desire for more high-quality 7.5-minute (1:24,000 scale) geologic maps. Also requested were more comprehensive and detailed stratigraphic studies and descriptions.

7. General approval was expressed within the group for the establishment of another CUSMAP project in Utah — either the Tooele, Delta, or Cedar City 2° quadrangle — to be carried out as close to the pattern of the recently completed Richfield CUSMAP project as possible. Delta was specifically recommended, since it includes nearly the entire length of the highly productive and highly prospective Tintic-Deep Creek mineral belt.

a. Industry representatives responded that their needs would be greater served by a band of 7.5-minute geologic maps along the axis of the mineral belt itself.

b. Within the Delta 2° quadrangle, the area of the Drum Mountains also was recommended for detailed study at 1:24,000 scale.

8. The comment was made that the geology, geochemistry, and economic aspects of many of the deposits of non-metallic and industrial mineral commodities were not being investigated by either the UGMS or the USGS, or by academia. Many opportunities exist in this general field of study for the application of a variety of scientific techniques. Special commodities of interest include: alunite, high-alumina and other special clays, metallurgical limestones, evaporite deposits and minerals, and high-silica commodities to name a few.

9. There was little interest in a discussion on the loss of major parts of several of the more productive mining districts of Utah for redevelopment or exploration because of the urbanization or non-mining use of patented mining claims, or the impact on mineral exploration by extensive withdrawals of several categories of wilderness lands.

10. It was noted that the mineral-resource investigations ideally should have a lead time of about 20 years and that uranium in particular should command some continuing interest from the USGS and the UGMS.

11. A general question was raised concerning the application of geophysics to the studies of ore deposits. The various so-called mining geophysical techniques, such as IP, SP, EM, and other electrical methods, have been disappointingly unsuccessful in discovering or evaluating ore deposits in the Great Basin, chiefly because the ore bodies are of relatively small dimensions, are deeply buried, and are extensively oxidized. Exceptions include the use of AFMAG techniques in the successful exploration and delineation of skarn ores in the Milford area, detailed ground magnetic studies in the Iron Springs district near Cedar City, and the many successful radiometric exploration projects in the Colorado Plateau area.

Gravity, aeromagnetic, and deep and shallow seismic geophysical studies are in an entirely different category. As our studies progress on the concealed morphology, deep structure, and crustal localization of the prominent mineral belts of Utah — and of the distribution, localizing features, and genesis of the mining districts — we will become almost entirely dependent on the use and application of these and other geophysical techniques. Many more of these types of geophysical studies, particularly the shallow seismic investigations, are highly recommended. ■

SURFACE MAPPING

Continued from Page 12

Selection Board made up primarily of representatives of other Utah State agencies in order to give them opportunity for helping to establish priority of quadrangles to be mapped, and 2) Map Standards Board made up of representatives from USGS, universities, and industry and charged with ensuring high quality of UGMS geologic map products by making recommendations pertinent to the production and review processes. The field review, as currently carried out by UGMS, was lauded for its efficacy in attaining broad based critiques of mapping efforts.

After passage of legislation in 1983 establishing the 7.5-minute geologic mapping program it became evident that a selection process for quadrangles was necessary so as to map more useful or needed quadrangles first and that areas already suitably mapped would not be duplicated.

Some geologic mapping covers most areas of the state, but it varies in scale, emphasis, depth, and detail. The following criteria were established to determine which quadrangles were presently suitable or would take care of most of the State's needs:

1. Quads with 1:24,000 mapping detail.

2. Completed quads, no corners or areas missing.

3. More than cursory attention paid to mapping Quaternary units.

4. Quads accurately tied to up-to-date USGS topographic quadrangles.

5. Quads mapped "on the ground" versus photogeologic or other generalized secondary mapping.

In addition, good 1:50,000 or 1:62,500 mapping would not be immediately considered to be redone. UGMS developed a map which was then introduced to various map selection committees established to make recommendations.

Quads were selected by previous mapping entities because:

1. They were needed as part of a bigger project, such as CUSMAP, the State Geologic Map, Paradox waste disposal study.

2. They involved important resource areas and became mining district maps (areas of mines, minerals, quarries, coal deposits, and so forth.)

3. They displayed an area of structural, stratigraphic, or igneous interest and were key to the decipherment of a regional problem solution.

4. They involved urban construction, highways, or geologic hazards.

5. They occurred in an area of general or public educational interest, such as areas of national parks, geologic wonders, scenic beauty, caves and caverns.

6. They occur where rocks are well exposed (teaching mechanisms for graduate students).

The present mandate is for mapping to be addressed in a multipurpose mode - not singly for mining, or structural, or stratigraphic interest, or hazards - but some combination. Accuracy is an important factor; the geology needs to be good enough to overlay property lines or to be used in court cases, to have the credibility presently accorded to topographic maps.

The present workshop is to provide suggestions from the scientific community. Currently UGMS is working on 6 quadrangles and has proposed three more to be mapped:

Aurora, Beryl Junction, Brigham City, Cutler Dam, Honeyville, Mt. Escalante, Pinion Point, Redmond Canyon, and Salina. In addition, the UGMS can increase its output of mapping quads with several types of cooperatives. UGMS can finance annually about 5 students who wish to map quads in Utah as part of their Master's programs. The contracts are awarded students on (1) the attractiveness of the proposal they submit and what support, innate abilities, or other strengths they will lend to the project, (2) whether or not their proposals fall into the list of 35 higher priority quads. UGMS also has cooperatives with universities and the USGS. UGMS has not tried to influence USGS as to locations or priorities, since it has their own, but eventually all quads will need to be systematically mapped, so this is no problem.

Finally, UGMS also has a county mapping program of 1:250,000 scale and mineral resource program to produce compilation at the 1:100,000 scale. Through the Survey Notes publication, UGMS hopes to publicize and keep track of what geology is being done in Utah, not only by USGS and UGMS, but any other agency or school, and hopes that everyone will cooperate in supplying the information to keep this activity successful.

7.5-Minute Mapping Recommendations

A complete and whole-hearted approval was given for the mapping program begun by the State of Utah. A few voiced their concern about the reviewing system. The process of review was reiterated and many wished to be informed when field reviews were to be scheduled.

The mining personnel and hazards people voiced their opinion to both UGMS and USGS that more 7.5-minute quadrangle mapping was necessary in mining districts and urban areas. Hal Morris recommended mapping quadrangles in the Blawn Mountains and Drum Mountain areas for the mineral (metallic and non-metallic) potential. The role of the UGMS should be to continue to map smaller mining districts and USGS should map in larger, more complex districts (such as Gold Hill), where lab support, and geophysical and geochemical support were important.

Mapping in key stratigraphic areas was suggested. UGMS was applauded for mapping the Wellsville Mountain area; additional suggestions included the south end of the Deep Creek Mountains, and the Bear River Range.

For research, in Quaternary and Tertiary geology, several quads were recommended including the Grouse Creek Valley area, Lehi, San Pete Valley, Cache Valley, and some glaciated areas in the Uinta Mountains and Wasatch Plateau. Key measured sections should be included in all of these map presentations.

Hazards people recommended mapping in key urban development and expansion areas such as in St. George, Cedar City, Price, Ogden, and Vernal.

1:100,000 Mapping

One of the more useful scales at which geologic mapping should be produced is 1:100,000 (which is replacing 1:125,000 as a standard map scale). Since suitable topographic bases are not quite completed for Utah, it was resolved that the USGS topographic division should be influenced to complete the series.

This was the scale of maps preferred by geophysists, geochemists, structural geologists; and would certainly be of great interest to the general public and planners. Programs already in progress were noted, such as some USGS 1:100,000 quads already in the mill. It was recommended that future CUSMAP projects should consider production of accompanying 1:100,000 maps.

Topical Studies Related to Quadrangle Mapping

In some instances it is not possible to make rational decisions regarding map units and their nomenclature by working only within the limited confines of a quadrangle. Stratigraphic nomenclative problems were identified that would benefit by regional stratigraphic work to establish the framework for better quadrangle map unit nomenclature. These are:

1. Precambrian nomenclature of west-central Utah. Nicholas Christie-Blick of Lamont-Doherty Laboratory of Columbia University in New York may be addressing this problem currently.

2. Cambrian stratigraphy of northeastern Utah. This will partially treated by UGMS mapper Jack Oviatt in his current mapping near Honeyville. BYU student Lea Berry is mapping in Blacksmith Canyon south of Logan. Mike Taylor, USGS paleontologist, recommended mapping on the southern end of Promontory Point to establish valid nomenclature for the fossiliferous Cambrian strata excellently exposed there. He said that the entire Cambrian nomenclature for northeastern Utah needs review - a large job.

3. Hal Morris noted the need for regional work to establish the relationship of the different Mississippian nomenclatures derived from southern Nevada (Monte Cristo), eastern Nevada (Joana), northern Arizona (Redwall) and central Utah (many names). Thrusting in western Utah has juxtaposed differing Mississippian sequences.

4. The Claron Formation (Paleocene?-Oligocene) needs to be abandoned or redefined. Work needs to be done to establish whether all units called "Claron" are really equivalent. Quadrangle mapping in Parowan Gap might help define this unit.

5. Workshop participants interested in hazards repeatedly urged stratigraphic work to establish Quaternary stratigraphy and map units. Mike Machette urged that studies similar to the USGS Beaver Basin team study would be fruitful and useful in dating movement on faults and landslides. No segment of the geologic column was deemed as critical to hazards work as the Quaternary and both mapping and topical studies of Quaternary areas were strongly recommended. ■

UGMS LIBRARY

BOOK REVIEW

Bibliography of Repeat Photography for Evaluating Landscape Changes, by Barry F. Rogers, Harold E. Malde, and Raymond M. Turner, 1984, University of Utah Press.

Repeat photography is the reoccupation of a camera site at a later time to make a new photograph of the same scene, to evaluate changes in the landscape.

Historically, the first such photos were made by Professor Sebastian Fensterwalder, the father of precise glacier mapping, who in 1888-89 initiated repeat photogrammetric surveys of glaciers in the Alps. Since then, matched photographs, showing the same subject at different times, have been used to show changes in such things as vegetation, effects of stream channel erosion, volcanic activity, mining districts, or movement on faults.

The book tells in detail how to take useful photos; it lists sources of existing photos, and gives an annotated bibliography by author and is indexed by subject and locality. The published material on the use of repeat photography is given from the perspective of geology, geography, and botany.

FROM THE DIRECTOR'S DESK

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ing awareness of county and local planners of geologic hazards has created an environment for responsible action.

To reduce our vulnerability to earthquakes requires a joint effort by all levels of government. I believe that the Federal government has the primary responsibility to perform and fund the research efforts that lead to an understanding of: (1) the earthquake hazard along the Wasatch Front, (2) the potential losses from earthquakes; (3) the systems needed to make earthquake information available for use. The State responsibilities include: (1) providing an example of responsible construction of State facilities, including consideration of seismic safety in design and construction and requiring geotechnical review of sites before the design of public buildings (preferably before acquiring the site); (2) compiling geologic information so it can be used by local governmental entities and by the public, and (3) providing advice and assistance to local governmentson seismic safety. Utah's county and city governmental entities have the responsibility for regulating land use and the protection of life and property. And all of us have the responsibility for personal preparedness. What surprises most people is that many of these actions do not require major expenditures to make significant improvements in safety.

Many of these actions are underway or are being considered for implementation. We are seeing several positive changes and the potential for major changes in the understanding and reduction of hazards along the Wasatch Front. For information on the USGS program, contact Wendy Hassibe (524-5652); for the UGMS program contact Don Mabey (581-6831); for the county program contact your county planner, and for information about personal preparedness, contact Laura Stowell, Comprehensive Emergency Management (533-5271). ■

Genevieve Atwood

In Memorium

Karl W. Brown, 61, died January 29, 1985, in Salt Lake City. He was petroleum geologist for the UGMS since 1979, and authored the annual *Summary of Oil and Gas Activity in Utah.* He was born in Provo, Utah; graduated from BYU in 1958; worked for 11 years as an exploration geologist; and then worked with the engineering section of the Utah State Dept. of Transportation. He was vice president of the Utah section of the AIPG. Karl will be missed by all of us here at the UGMS.

GREAT SALT LAKE LEVEL

Date (1984)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
Nov. 1	4208.05	4207.05
Nov. 15	4208.20	4207.20
Dec. 1	4208.30	4207.35
Dec. 15	4208.40	4207.45
Jan. 1, '85	4208.65	4207.70
Jan. 15, '85	4208.80	4207.90

Source: USGS provisional records.

UTAH DEPARTMENT OF NATURAL RESOURCES
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, UT 84108-1280

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